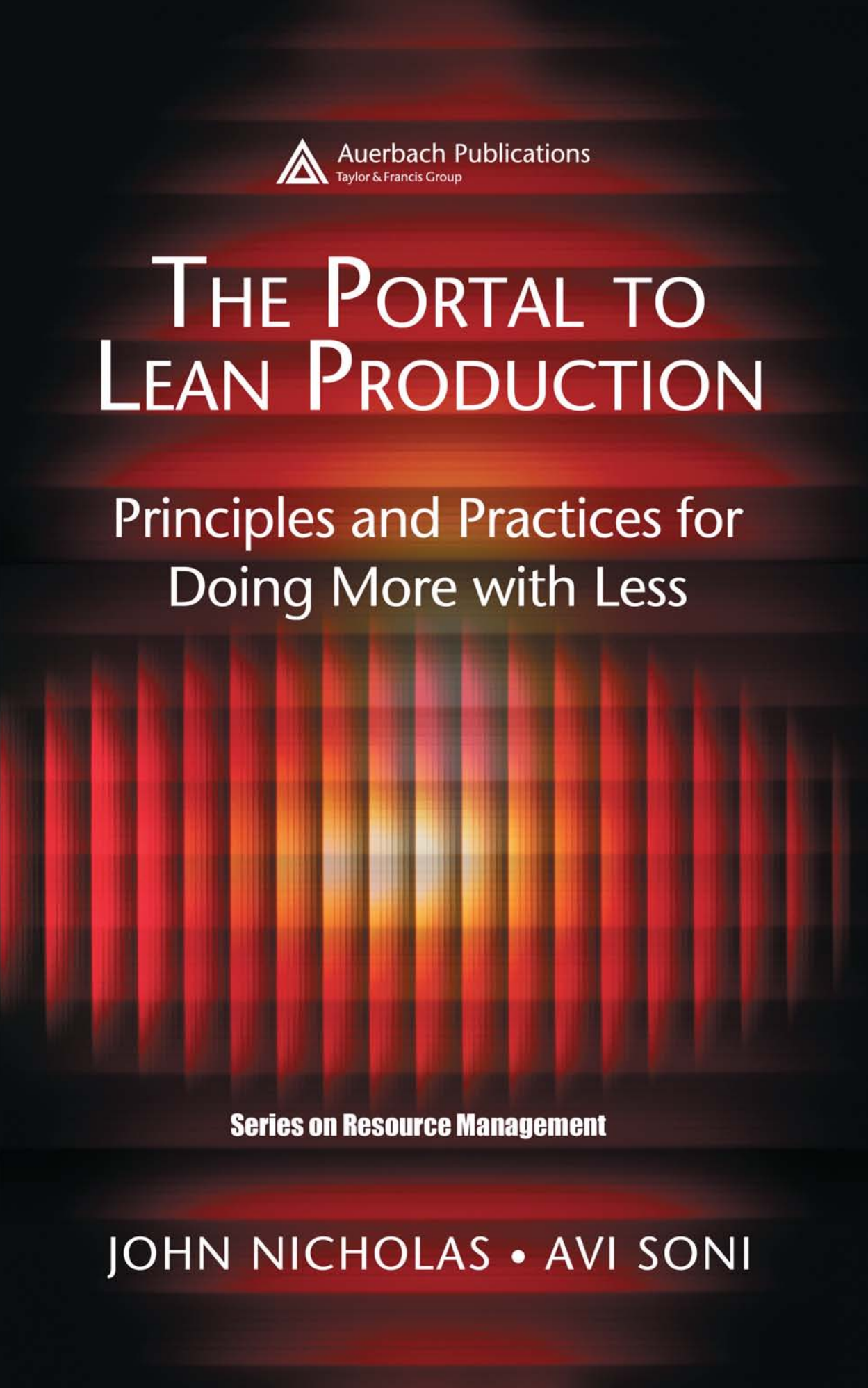
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JOHN NICHOLAS • AVI SONI

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Preface

We grew up in awe of the things around us — especially things that are manufactured and products of technology — and we dreamed that one day we would both help design and make those things. So we did what kids who are dreamers sometimes do: we studied engineering in college and took jobs in corporations that build things. Years later, John ended up as a professor; Avi became a manufacturing engineering manager. Who had more fully realized his dream or was having more fun, we cannot say.

Although on seemingly divergent career paths, our lives crossed because of a passion we shared, not dissimilar to the one we had as boys: besides an interest in building things, we also cared about the way businesses go about doing this. We had both, it seems, developed the same conviction, and when we became acquainted and shared our experiences we realized that we sought the same goal with that conviction: to share it with as many others as we could. John already had a vehicle for that — the classroom — but Avi had none. He had done as much as he could to spread his conviction in the company where he had worked, but now — approaching retirement — he needed a way to keep on sharing it. Hence the genesis of *The Portal to Lean Production*.

This book is about our passion, which is not just to build things but to also build them in the best way possible. We are convinced that, in manufacturing, the best way is lean production. Certainly, we were not the originators of or even contributors to the idea of lean production, nor is our conviction that it is the best way unique. The principles, concepts, and techniques of lean production can be credited to the innovation, foresight, and genius of many others, and millions of others today share our belief about it. But that is not to say that all or most managers are familiar with lean production or are eager to adopt it. Far from it.

Adopting lean production is not something that happens easily: like most meaningful, substantive things, you first have to understand the

concepts. And beyond intellectual understanding, you have to see for yourself in practice what it means and how it works. You must be diligent at learning the concepts and even more diligent at applying them. But once you understand the concepts and see the practical benefits, we suspect something interesting might happen: you will develop a passion for lean production and want everybody else to know about it. We have encountered numerous people as proof that that can happen!

We wrote this book to tell readers about lean production. We wanted to describe our journey through lean production; however, we also wanted to go beyond our journey so that interested readers would know how they might begin the journey through lean production on their own. The story about lean production is like a movie that on occasion has been re-released, but each time with a different title. Fifty years ago lean production was called Toyota production system (TPS), then later just-in-time (JIT), zero-inventory, and world-class manufacturing. We cannot say what lean production will be called tomorrow, but our conviction is that lean production is the best way known to manufacture things, and it will remain so in the foreseeable future. Our hope is to instill in you enough interest and knowledge so you too will want to start on the journey.

Each chapter contains italicized portions that represent Avi's story relating to topics of that chapter. Although it may appear that the story portions were written by Avi and the remaining parts by John, in general both authors made contributions throughout the book.

John Nicholas
Avi Soni

Acknowledgments

The experiences related in this book come chiefly from two sources: ITT Hoffman Company in Indianapolis and ITT McDonnell and Miller Company in Chicago. We would like to acknowledge all the people in those plants who walked the initial steps with Avi and at M&M helped create a lean production environment. There were many who participated in the events we describe, but Sung Yong, Jun Manalo, Jung Choi, and Keith Kornafel deserve special mention. We also wish to recognize Roger Murphy and Bob Dvorak, general managers at M&M, for their support and sponsorship, and Chitra Prahkaran and Kathleen King, our assistants, for research and administrative support.

And a special thank you to our wives, Sharry and Kamlesh, and to our children, Josh and Abbie and Anjili and Anil, for their continuous encouragement.

The Authors

Avi Soni, left, and John Nicholas, right.

John Nicholas is a professor at Loyola University, Chicago, where he has taught operations management since 1977 and lean production since 1990. Prior to teaching, John was an engineer in the aerospace industry and a business systems analyst in banking.

He is the author of many articles and three textbooks: *Managing Business and Engineering Projects*, *Competitive Manufacturing Management*, and *Project Management for Business and Engineering*. He has B.S.A.E. and M.B.A. degrees from the University of Illinois and a Ph.D. in industrial engineering from Northwestern University.

Avi Soni recently retired from McDonnell & Miller Company (M&M) where he worked since 1989 as manager of manufacturing services and quality assurance. (M&M is owned by ITT; in 2003, M&M earned a $13 million operating profit, making it one of ITT's most profitable companies.) Before M&M, he was director of operations analysis at Cummins Engine Company and manager of manufacturing engineering at both ITT Bell & Gossett

Company and ITT Hoffman Company. He is a Six Sigma Green Belt and has a B.S.M.E. from Delhi University, an M.S.I.E. from Columbia University, and an M.B.A. from Fairleigh Dickinson University.

Chapter 1

Portal to Lean Production

My name is Avi. I have spent most of my life as a manufacturing manager and engineer. As a young manager years ago, I was perplexed about why I was unable to turn around a manufacturing plant and prevent its being closed. I am still saddened to see so many plants throughout the United States shut down and so many jobs lost — especially because I believe I know how in many cases that might be avoided. This is not to say that preserving U.S. manufacturing jobs should be at the expense of manufacturing jobs in other parts of the world, or vice versa. Nations everywhere need healthy manufacturing sectors to meet growing product demand and provide jobs to their own populations, and I believe that producers everywhere can coexist without necessarily threatening each other's existence. But the reality is, it seems, one nation's gain is another's loss, at least for the present.

I grew up in a country where there was no manufacturing. The barest necessities and conveniences of modern society — like the little clips that hold a sheaf of paper together — had to be imported. I dreamed as a boy that someday I would be able to make things that people wanted and could use. I was lucky because I had the chance to live out that dream. More than that, I was able to experience

and participate in the astonishing changes that have revolutionized manufacturing in the last 50 years. Throughout my career and especially in the last few decades I learned a great deal about manufacturing. The principal influence on my thinking and behavior as a manager was the Toyota Production System (TPS), or — as it is more typically referred to — the concept of lean production. The stories that begin each chapter in this book illustrate the impact TPS and lean production have had on me and on the companies where I have worked.

The answer to the plant closure problem came to me after I started to question traditional ways of mass production and to conclude they are no longer sufficient to make a plant profitable or stem the pace of manufacturing decline. It took me 20 years to answer the question of what is the best way to organize and execute a manufacturing process to make it competitive. The answer, I am convinced, is lean production.

1.1 Race with a Moving Finish Line

1.1.1 Center of the Manufacturing Universe

It used to be that people everywhere looked to one place in the world for manufacturing capability and production efficiency: the United States. Not only did U.S. companies outproduce companies everywhere else, but the United States was the main source of all manufacturing innovation. Anyone who wanted to learn manufacturing had to go to the United States.

Immediately after World War II — at a time when the manufacturing capability of most of Europe and Asia had been largely reduced to rubble — the United States alone stood as supplier to the world. The manufacturing might of the United States — its production of phenomenal numbers of planes, ships, tanks, bombs, and every other form of weapon — had overwhelmed the Axis powers and beaten them into submission. After the war, that same might was quickly redirected to the production of peacetime goods to meet pent-up demand from consumers and industries throughout the world. In the decades since, however, producers everywhere have emerged and grown to challenge the manufacturing might of the United States. The center of the manufacturing universe has moved elsewhere.

Manufacturing is still the cornerstone of the world economy; manufacturers all over the world compete directly for customers in markets that span the globe. They are part of a never-ending race among innovators and producers, a race where winners prosper and grow and losers struggle and disappear. It is a race where the finish line keeps moving ahead.

In the remainder of this chapter we describe the nature of the race, the role of lean production, and why lean production is different and not universally accepted. We also introduce the Portal to Lean Production — a model for organizing the concepts of lean production — and describe the organization and chapters of the book.

1.1.2 Customer Expectations

The finish line is customer expectations. It keeps moving ahead because customers are forever expecting more of everything: better service, faster delivery, and unimaginably higher levels of quality, all at a reasonable price. Time was, the price could be set by the manufacturer by simply starting with the production cost and adding a profit margin, i.e., price = cost + profit. No more! In competitive markets these days, the price is set by the market — a combination of customer expectations and eager competition. Hence, any profit to be earned must be squeezed out of the price by manipulating cost, i.e., profit = price – cost. And, of course, a minimum profit must be set to enable the company to stay in business and meet shareholder expectations, which leaves cost as being the only control variable. Thus, the only way to maintain or increase profit is to forever reduce cost, in the meantime being sensitive to customer expectations — that is, to reduce cost but not lessen quality or customer satisfaction. Indeed, the quest to reduce cost must be accompanied with an eye on increasing product quality and customer satisfaction.

In a world of such high customer expectations and fierce competition, it is no easy matter for any producer to keep up. Many do, of course, although the most noteworthy do not simply keep up, they actually lead the race by *exceeding* customer expectations and, along the way, beating the socks off the competition. So the finish line keeps moving, shoved ahead not only by customer expectations but also by the efforts of exceptional producers.

1.1.3 Everyone Is in the Race

Participation in the race is not an issue: if you are a manufacturer, you are in. The issue is, how long will you stay in? Somewhere in the world there are companies that will enter or have entered your market and will be vying for your customers. If you want to stay in the race — stay in

business, prosper, and grow — you must be able to perform at least as well as they do. If you cannot meet customer expectations and outperform the competition, wherever it is, you will not survive. You already know this, but read on.

1.2 Awakening to Lean Production

This book describes what is necessary to stay in the race. It is about one manager's personal journey through manufacturing and his awakening to a philosophy called *lean production*. As the next chapter describes, lean production originated at Toyota as a fundamentally different way of approaching manufacturing. Today, producers all over the world are adopting lean production. Most managers have heard about lean production; almost as many, it appears, still do not get it.

1.2.1 Abandoning Manufacturing

The rapid rate of plant closures and of production outsourcing suggests that many U.S. manufacturers are perhaps in denial: they think either they are not part of the race or have options other than lean production to be competitive, including outsourcing of manufacturing or increased effort at traditional ways of mass production.

The current popular trend is toward offshore outsourcing of almost everything to be manufactured. The unintended consequence of this is the "hollowing out" of companies and even entire industries as more manufacturing work, expertise, and profits are transferred to offshore producers. We submit that, though perhaps not consciously, these companies have essentially decided to exit the manufacturing business. When a company outsources the manufacture of its products, it eventually relinquishes its manufacturing capability while it also nurtures the manufacturing capabilities of its suppliers. At the same time that its own manufacturing competency is shriveling for lack of use, its suppliers' competencies are growing from experience. As the profits and manufacturing capability of the offshore supplier grow, so does its design and distribution capability. In time, the offshore producer that once was only a manufacturer becomes strong and capable enough to become also the designer and distributor for the things it manufactures. Perhaps, eventually, it becomes a formidable competitor to the companies it formerly supplied.[1] Those companies, having abandoned manufacturing, are left in the dust. Use it or lose it; if you do not do something, you can never get better at doing it.

The U.S. television industry is a famous example. Once virtually all TVs sold in the United States were produced in the United States. At first,

a few of these producers outsourced some TV production to offshore suppliers, then gradually more. The overseas TV suppliers improved their processes — got better and better, lowered their costs and improved their quality, which gave their customers a competitive edge. Other U.S. TV producers had to follow suit; they too had to outsource production just to stay in business.

But a (not so) funny thing happened. Those overseas suppliers grew to become industrial giants — in no small part thanks to the huge TV manufacturing contracts they had had with big U.S. corporations, and they decided to begin offering their own brands, sometimes in direct competition with the brands of their customers. But their customers had no recourse, for they had lost the capability to manufacture TVs and would never be able to get it back. Today, no TVs (the electronic portion) are made in the United States, and many of the former big-name U.S. TV producers no longer even exist. The TV market leaders of the past are unknown or defunct.

Interestingly, the original basis of an offshore supplier's competitive advantage — a reason why it is chosen as a supplier in the first place — is the ability to do things better and cheaper, not necessarily because of lower wages. In many industries that ability stems from suppliers already having embraced a different way of manufacturing through the philosophies and practices of lean production.

1.2.2 Lean Is Different

Many managers think they can improve manufacturing competitiveness by working harder at the same methods they have used for decades. Everyone has heard about lean production, but some managers believe that it is not for them. They believe it is not doable or would be too costly to adopt. They may be "entrenched" — ignorant of different ways of production or not interested in changing. Every organization has at least a few entrenched employees — white collar, blue collar, managers, and senior executives. People experienced in lean production, the "advocates" of lean, often have empathy for them — maybe they too were once entrenched. The advocates know, however, that what once had seemed impossible is not only feasible but is also readily doable and affordable. What once had seemed bizarre is really common sense. The mission of the advocates is to win over the entrenched.

Winning them over is not easy though. Lean production methods *look* different to most managers and shop floor employees. In truth, as we shall illustrate throughout this book, lean production methods and principles *are* different, despite the fact that they conform to the principles of good

production management, some that date back to Henry Ford and Frederick Taylor. But because they appear different, the common perception is that it must take tremendous effort to become a lean producer. In fact, it *does* take tremendous effort, although the effort does not have to be expended all at once or quickly. Nor does the effort have to be a futile struggle against the resistance of the entrenched.

1.2.3 Resistance to Lean

A few words about resistance to change are in order as they relate to the stories in this book. The resistance that accompanies any organizational change is a function of the *magnitude* of the change and the *rapidity* of the change. The bigger the change and the faster it happens, the greater the resistance will be. An analogy is a new tooth: as it starts to come in, it pushes out the old one. Somewhere in the transition, though, you have to *pull it out*. You can pull it out as soon as you feel it loosening, or you can wiggle it with your tongue for a few weeks and eventually it will come out, almost on its own. The first way is quick and bloody; the other is slow and relatively painless. The same applies to becoming a lean producer. Many successful lean transformations, including the one described in this book, have inconspicuous beginnings and develop slowly. Over time, resistance dwindles and converts are won. There is little drama but also little pain. The entrenched become advocates.

Toyota, the originator of lean, first implemented lean methods over 50 years ago (having even before then begun to practice a few "predecessor" elements of lean production). It devoted the first decade to developing the principles and methods of lean and the next four decades to improving and expanding them. The philosophy that Toyota embraced — and still embraces today — is to work continually, sometimes slowly, but always toward making progress and improvement. The Japanese term for this philosophy is *kaizen*. Holding to the kaizen philosophy, any organization can become a lean producer — and without too much pain. Becoming a lean producer takes tremendous effort and constancy of purpose, but the effort does not have to be expended all at once. The better way is to start small, demonstrate success, and win over the hearts and minds of the entrenched.

Nonetheless, it can be especially difficult for advocates to sell top management and investors on the philosophies and concepts behind lean production. Two overarching philosophies of lean production are "elimination of waste" and "continuous improvement," and such philosophies are not something a plant manager can readily translate into specific actions on strategic and operating plans, or assign specific dollar values

for expected benefits. Necessary to overcome resistance against lean production and win acceptance are "the three P's" of persistence, patience, and proof of benefits through demonstrated results. This book provides ample illustration of the three P's through stories and examples.

1.2.4 Universal Application

One argument the entrenched hold against lean production is that it applies only to automobile production. The argument is perhaps understandable given the origins of lean at Toyota and its impact on the automobile industry; it is, however, incorrect. The concepts of lean production apply to a vast range of operations and processes in widely differing industries: aircraft manufacturing; insurance-company claims processing; offices and health care, to name a few.[2] Avi applied them to the manufacture of switches and control units — an example of lean production in a medium-sized company that belongs to a huge conglomerate. The concepts of lean are robust and can be applied to a wide variety of industries — with only tweaking of the details.

1.3 The Portal

The philosophy, principles, and techniques that make up lean production are conceptualized in the model in Figure 1.1, the Portal to Lean Production.[3] The terms and concepts in the model will be fully explained in the book, but for now think of the portal as the entrance to a lean production plant, a plant that benefits from lower cost, higher quality, and shorter lead times than other organizations. The benefits result from the plant abiding by the overarching philosophies of lean production: elimination of waste and continuous improvement.

1.3.1 Elements of the Portal

As suggested by the model, the philosophies "rest" on fundamental principles, represented in the model as pillars. For simplification, the principles have been arbitrarily combined into four:

- Six Sigma quality/Robust design
- One-piece flow
- Total productive maintenance/Kanban replenishment
- Supply-chain partnerships

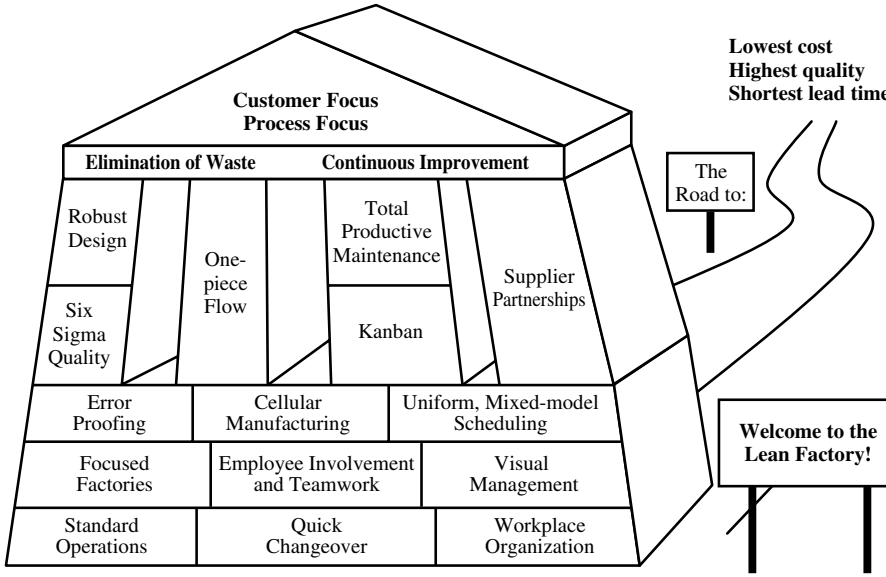


Figure 1.1 The Portal to Lean Production

An organization that is lean abides by the philosophies by adopting day-to-day practices that make the principles come alive. In the portal, these day-to-day practices are represented as foundation blocks, which are the techniques and practices of lean production. The actual techniques and practices of lean production are numerous, although lean advocates tend to agree about which are most basic or fundamental. The foundation blocks shown in the model are techniques and methods commonly associated with lean production:

- Error proofing
- Uniform, mixed-model scheduling
- Cellular manufacturing
- Focused factories
- Quick changeover
- Standard operations
- Employee involvement and teamwork
- Workplace organization
- Visual management

1.3.2 Application of the Model

Despite the appearance of the model, adopting lean production is not quite like building a physical structure. To start, you do not need to put all the foundation blocks (practicing all the methods) in place before putting up some of the pillars (adopting the principles), nor do you have to erect all the pillars before putting on the arch (embracing the philosophies). Rather, you start in your organization by choosing any of the blocks and then some of the pillars, according to the situation and the appropriateness, importance, convenience, economics, or familiarity of those blocks and pillars. Start with enough foundation blocks to put up one pillar, and that might be enough to support a lightweight version of the philosophies. Add more blocks and pillars, strengthen them with mortar (experience and lessons learned), and then add still more. This process can be lengthy, but eventually there will be enough of a structure such that the complete arch will go on top, almost by itself. What's essential to point out, however, is that ultimately *all* the blocks and pillars in the portal must be put in place, because only then will the arch be truly strong and the whole structure self-perpetuating (i.e., for an organization to live by the philosophies of elimination of waste and continuous improvement, it must adopt all the underlying principles and practices of lean production). As you will see, adding more blocks and pillars and improving them through experience makes the organization ever more lean and ever more a formidable competitor.

Another way of saying this is that lean production is a system, and it must be treated as one. Managers who become familiar with only one or a few principles or methods and then try to implement them will be disappointed. The principles and practices of lean production are mutually reinforcing. You need to implement some before others, and you need to implement a certain "critical mass" of them before you begin to see sustainable benefits.

1.4 The Organization of the Book

Elements of the portal are described from here on with stories from Avi's experience and as generalized concepts. Terms in the model as well as others associated with lean production (below, in italics) are defined in the glossary and elaborated throughout the book.

The next chapter provides a brief history and introduction to the concepts of lean production as developed in TPS, the *Toyota Production System*. It is Toyota and its owners and managers who should receive the

greatest credit for having originated the philosophy, principles, and majority of practices in lean production.

From Chapter 3 on, principles and methods of lean production are covered in detail, roughly in the order that Avi learned about and adopted them in his plant. Most chapters introduce the concepts through a story or vignette from Avi's experience. After the story, we describe the concepts and methods in depth so the reader can begin to apply lean production to other organizations.

Avi's journey began with implementing a *manufacturing cell* in response to pressure to improve the profitability of a product line. Once the advantages of cellular manufacturing became obvious, he expanded the concept to other product families and, eventually, to the entire plant. The concepts and application of manufacturing cells, *one-piece flow* and *uniform, mixed-model scheduling* are described in Chapters 3, 4, and 5.

Some of Avi's larger manufacturing cells consisted of subcells, with material flowing from one to another. A way was needed to balance this flow, and the way chosen was a *kanban* system. Experience gained about kanban from these cells allowed Avi to see broader applications and to employ kanban as the link and control mechanism for material flow between cells and operations everywhere in the plant. Eventually, the kanban system was expanded to link the plant with its outside vendors. Kanban, and the more general concept of *pull production*, is introduced in Chapter 5 and fully explained in Chapter 6.

With more and more cells in operation, the necessity of preventive maintenance quickly became apparent. If just one machine broke down, the whole production process stopped. The mandate was to have no more breakdowns. This became the incentive for adopting *total productive maintenance* (TPM), the topic of Chapter 7.

Product variety, minimum equipment downtime, and low variability in output require that equipment be rapidly changed over and that operations be standardized so everyone does the same work in the same way. While implementing workcells and kanban, Avi discovered the importance of *quick changeover* (setup) times and *standard operations*. The techniques for these are described in Chapters 8 and 9.

Before Avi's arrival, the plant where he worked had been organizationally subdivided into *focused factories*, but plant management and operations did not reflect the enlightened attitudes toward shop employees that usually accompany lean production. With the introduction of cellular manufacturing, the company began a shift toward more autonomous management of each focused factory and greater employee involvement. Focused factories are described in Chapter 10.

Six Sigma, a disciplined, data-based approach for eliminating defects and improving processes, was adopted at Avi's company out of necessity

to resolve customer complaints. The company had a prior excellent quality reputation, which allowed it the luxury to analyze, understand, and address particular complaints and to get to the root causes of quality problems. The Six Sigma quality initiative they adopted, which is based on Motorola's quality philosophy, and methods for problem solving, statistical process control, and error proofing are the topics of Chapter 11.

Continuous improvement in organizations, *kaizen*, happens through the ongoing efforts and projects of worker associates directed at resolving problems and removing waste, and requires high-level *employee involvement*. Chapter 12 describes the role of workplace organization in garnering worker discipline and attitudes toward improvement, and a *value-stream-mapping* project as an example of improvement tools in common practice.

Having substantially modified the plant to conform to the principles of lean production, Avi expected that quality defects would all but disappear, but they did not. Most manufacturers rely heavily on suppliers for a portion of the content of their products, and his plant was no exception. Chapter 13 describes the critical role of *supplier partnerships* in lean production.

Even though the main focus of lean production is initially directed at the processes that produce goods or provide services for the customer, soon most other functional areas of the organization are also drawn into the lean effort. As told in Chapter 14, product design, purchasing, accounting, marketing, and human resources are all influenced by lean production and must adapt to it before lean production efforts can succeed.

Without question, lean production will not take root or become self-perpetuating until the organizational culture is such that most everyone embraces lean principles and philosophies. Chapter 15 describes the culture of lean production, how it differs from other cultures, and implications for successfully adopting and sustaining lean production.

The philosophy and techniques of lean production have revolutionized manufacturing; however, they are no longer revolutionary. They have become the standard of what contenders in the race must do to catch up with the pack, stay with it, and take the lead. This book does not dwell on everything a company has to gain from adopting lean production nor all it has to lose from not adopting it. Simply, it attempts to strip away mystique and misconceptions and to describe in plain language what it means to be a lean producer and how to become one. By the end of this book you will have an understanding of lean production and see how to implement it. And you will discover that, like Avi, you can do most of this on your own.

Let the journey through the portal begin.

Notes

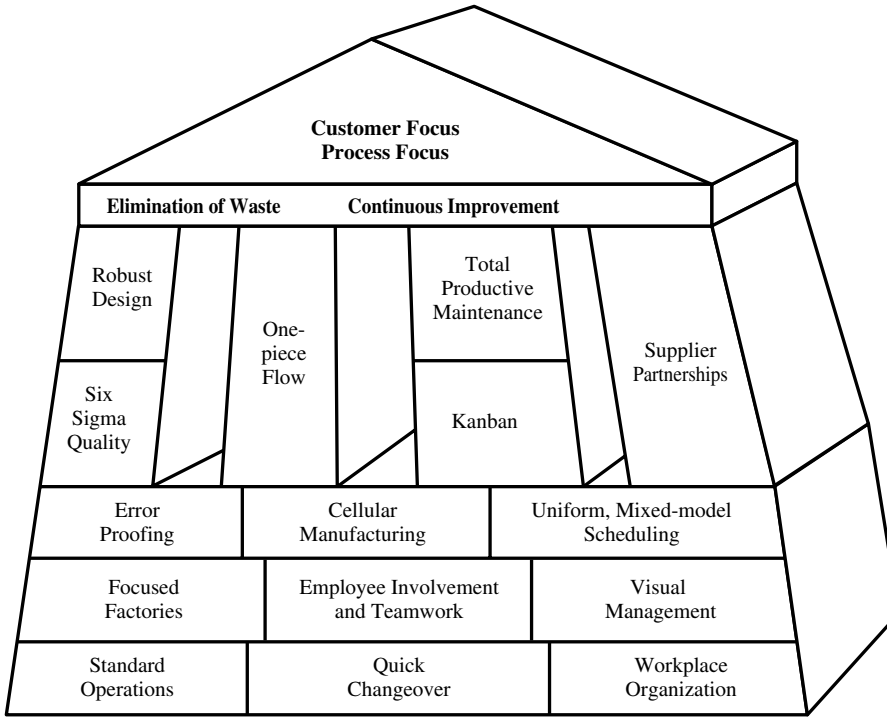
1. Bettis, R., Bradley, S., and Hamel, G. Outsourcing and industrial decline, *Academy of Management Review*, 6(1), 7–22, 1992.
2. Examples of lean applications abound. For examples in aerospace, see Ruffa, S., Perozziello, M., *Breaking the Cost Barrier*, John Wiley, New York, 2000; for textiles and retailing, see Abernathy, F., Dunlop, J., Hammond, J., and Well, D., *A Stitch in Time*, Oxford University Press, New York, 1999; for insurance, see Swank, C., The lean service machine, *Harvard Business Review,* Oct. 2003; for office environment, see Tonkin, L., Lean office: mapping your way to lean, *Target*, fourth quarter, 2004; and for health care, see Panchak, P., Lean health care? It works!, *IndustryWeek*, Feb. 2004, http://www.industryweek.com/current articles/. For case illustrations of lean production in all kinds of industries and companies big and small, see *Target*, the quarterly publication of AME — the Association for Manufacturing Excellence, based in Arlington Heights, IL.
3. Readers familiar with the literature on lean production, JIT, and TPS will recognize the similarity in appearance between the portal and the "TPS House." Variants of the TPS House have appeared in many publications; we do know the origin of the House but suspect it is in an early Toyota publication. We acknowledge the influence of the TPS House in our design of the portal.

1

THE JOURNEY, FIRST STEPS

Chapter 2

Beginnings



I came to the United States, my adopted country, in the late 1960s to study mechanical engineering. After graduation I was able to pursue my dream to make things by taking a job as a manufacturing engineer at a small company that produced centrifugal pumps. Following in the footsteps of my predecessors, I eagerly applied the methods of "mass production," which included emphasis on economic order quantities and producing things faster and cheaper.

Several years and a few companies later, after I had become a manager of manufacturing engineering, ITT Fluid Handling Division offered me the job of turning around a small Indiana plant that was in trouble. The plant, Hoffman Specialty Manufacturing, had previously shown ROS's of about 7.5 percent but was stagnating at 1.5 percent. I accepted the offer and moved to Hoffman to become director of operations.

In my first year I tried everything I knew, mostly aimed at speeding up processes. No matter what we tried, nothing in the plant was turning around. So I began to look for other approaches, including some nontraditional ones. One that I came across was called the Toyota Production System in a book by the same name, authored by Yasuhiro Monden. In later years, concepts of this system would form the basis for what today is called lean production. The book — a translation from Japanese of a technical report — was very difficult to understand. I am a technically minded person and comfortable with complex concepts and quantitative material, but to me the concepts in this book were arcane, baffling, and downright bizarre. The system the book described was so different from anything I had experienced that I could not believe what I was reading; even less could I conceive of applying those concepts to my plant. I was not aware of any other books on the topic or of anyone familiar with the concepts, so I had to try to understand everything on my own.

One result of reading this book, however, was that it raised uncomfortable questions in my mind about why we (practitioners of traditional mass production methods) were doing things the way we did. In the meantime, circumstances